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In physics, conservation laws are statements that overall amounts of certain physical quantities remain the same in the course of a given isolated process. Among the most fundamental laws are those for MASS, ENERGY, linear MOMENTUM, ANGULAR MOMENTUM, and electric CHARGE. For example, the law of conservation of mass applies to chemical reactions. It states that the total mass of an isolated reaction does not change from beginning to end. That is, mass is neither created nor destroyed. The conservation law for linear momentum states that both the overall direction and the magnitude of the momentum remain unchanged, because linear momentum is a vector quantity (see VECTOR ANALYSIS).

The conservation law for electric charge is fundamental, there being no known exceptions. This conservation law applies to the algebraic sum, or total charge Q, of a system, which is defined as $Q = P - R$, where P is the amount of positive charge and R is the amount of negative charge in the system.

The law of conservation of energy is now one of the most important and firmly established conservation laws of nature, although it has been necessary to recognize that energy may occur in many different forms and is also equivalent to mass. Perhaps the simplest form of energy arises from motion, where the KINETIC ENERGY of a particle of mass m, moving with speed v, is defined as (1/2)mvv. The total kinetic energy of a system of particles is the sum of the kinetic energies of the individual particles. When work is done on a particle, the increase in kinetic energy of the particle is equal to the work done. For a system of many particles, the total work done on all the particles is equal to the increase in kinetic energy of the whole system. If the net work is zero, kinetic energy is conserved. This network must include work done by internal forces of the particles acting on each other. Thus, when a skater spinning with arms outstretched pulls them in, he or she spins faster (with increased kinetic energy) because of the work done on the body. In this example, angular momentum is conserved because there are no external torques.

Because an isolated system can experience an increase in kinetic energy, energy of some other form must be involved for the energy conservation law to be valid. This fact is evident in the case of a simple pendulum. As the pendulum swings back and forth, its velocity and hence its kinetic energy change; at the highest point, its kinetic energy is zero. Hence POTENTIAL ENERGY must be introduced. For the pendulum the potential energy is equal to Wh, where W is the weight of the pendulum bob and h the height above the lowest point. Here kinetic energy and potential energy are changing, but the total energy E = (1/2)mvv + Wh is conserved.

In macroscopic systems characterized by temperature, pressure, and volume, the law of conservation of energy is known as the first law of THERMODYNAMICS, in which heat is recognized as a form of energy (see HEAT AND HEAT TRANSFER).

There appears to be a connection between conservation laws and symmetry in nature (see SYMMETRY, physics). Every conservation law apparently corresponds to a particular symmetry. For example, in nuclear reactions, the total baryon number--the difference between the number of baryons (neutrons and protons being the most common) and antibaryons--is believed to be an exactly conserved quantity. Finally, there are processes in which some quantities are approximately conserved, and there are quantities that appear to be conserved for one kind of process but not for some others. The tenets of laws of conservation and symmetry can sometimes be used by physicists to predict the existence of undiscovered particles and forces, as in the case of the ELECTROWEAK THEORY.

W. E. Brittin and N. Ashby

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